Integrated Assessment of Air Pollution Abatement Strategies in Urban Areas:
Application of OPUS-AIR to the Greater Athens Area

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Abstract

OPUS-AIR is an integrated system, for the assessment of technical and non-technical measures that are put forward in order to reduce air pollution levels in urban areas. In contrast to the majority of the currently employed assessment tools, OPUS-AIR allows for the evaluation of any proposed air pollution control measure in terms of its combined impact on air quality and social welfare, by correlating the environmental and economic aspects of alternative air pollution abatement solutions. Based on the multi-pollutant, multi-effect concept, the system presented aims at providing policy-makers a reliable tool for the objective assessment of the most cost-effective packages of measures, the latter being allocated according to the particular features and needs of the areas examined. The innovative feature of OPUS-AIR is the quantification (internalisation) of the external costs (externalities) caused by air pollution and environmental degradation.

Introduction

Over the last decades, human activities led to the continuous increase of air pollutant emissions into the atmosphere. As a result, the atmospheric content has changed. Nowadays, air pollution on the urban scale has become the source of a range of problems: Health risks mostly associated with inhalation of gases, accelerated deterioration of building materials, damage to historical monuments and to vegetation within and near the cities. In order to tackle these problems, efficient, long-term air pollution abatement strategies need to be traced and implemented.

The adoption of an air pollution abatement strategy has the ultimate target to reduce sufficiently air pollution levels in the areas of implementation. Forming long-term, successful air pollution control strategies requires, however, knowledge of the costs associated with their implementation, the economic benefits that might result from the reduction of both the quantities of pollutants emitted and their concentrations in the atmosphere, as well as other possible benefits (or damages) arising from the adoption of the proposed strategies. In this sense, the selection of the most appropriate and most efficient bundles of emission control measures needs to satisfy a variety of criteria and, thus, should be conducted on the basis of the multi-criteria analyses and the decision–making theories (Yu, 1990).

In contrast to the above remarks, until recently the impact of air pollution control strategies was primarily assessed in terms of their influence on the pollution levels of the area considered. The economic impact arising from the application of the proposed measure(s) was, in general, neglected. If we accept the environment as an economic commodity, then it becomes self-evident that any form of environmental degradation comprises an economic commodity itself. Nevertheless, since the value and the contribution of the environment are systematically underestimated, the monetary valuation of environmental degradation is, in many cases, still not feasible. At the same time, however, mankind incurs an important financial burden caused by the decrement of social prosperity when the latter is not compensated.

OPUS-AIR as an integrated tool for assessing air pollution abatement strategies

Basic structure and components

OPUS-AIR involves a three-step analysis to be followed for conducting an integrated assessment of various air pollution abatement strategies. Based on the principles of the cost-effectiveness theory, the first step has a twofold purpose: a) to provide information on the total implementation costs and on the impact of the proposed strategy on the emission sources and air quality of the area examined, and b) to form the basis for constructing cost-curves for selected pollutants, the latter allowing for a comparative assessment of alternative solutions proposed by correlating the relative abatement costs with the benefits in terms of the achieved emission reductions in the area of interest (Friedrich and Reis, 1999). Accordingly, the proposed measures/strategies are evaluated in terms of their impact on air quality. The assessment is performed by constructing the emissions inventory for each emission situation examined (e.g. by quantifying the impact of the measure on the pollution sources and reproducing the spatial and temporal resolution of pollutants emissions) and, then, applying the European Zooming Model (EZM) system. The latter is a comprehensive group of models for simulating the transport and chemical transformation of air pollutants on the local-to-regional scale (Moussiopoulos, 1995). In the last step, the economic benefits on account of air quality improvement with regard to human health, human productivity and other ecosystems are evaluated (cf. section 2.3). For the cost-benefit analysis the damage function approach is adopted.

The interrelation between the basic components of the OPUS-AIR system is presented in Figure 1. As shown, the assessment of the proposed strategies is conducted a) through the comparison of the current air pollution levels with the concentration levels resulting after the hypothetical implementation of the abatement measure and b) having as a criterion the minimisation of the total costs required for (implementation costs) or arising from the adoption of the measures (externalities).

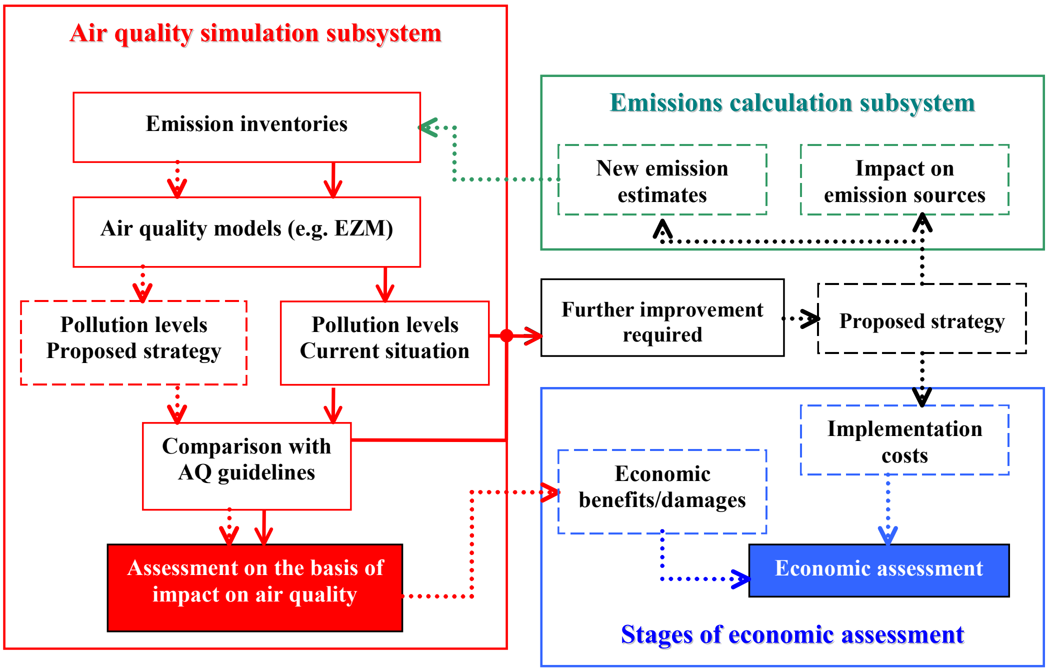


Figure 1. Flow diagram of the OPUS-AIR system for the assessment of pollution control strategies.

Estimation of the total costs

The total implementation cost of a pollution abatement strategy is estimated by summing up the fixed (C_{fixed}) and variable ($C_{variable}$) cost components. The former account for the investment and labour costs, whereas the latter, comprising of time-dependent quantities, include the annual amounts of operation and maintenance, energy and recovered costs.

If alternative measures are to be compared by the system, the optimum solution at this step is defined as the measure that may be enforced with the least cost while resulting to maximum reductions of the air pollutants emitted. In this case, the cost-curves for selected pollutants are constructed. A pollutant specific cost-curve correlates the total annual cost ($C_{total,an}$) with the corresponding emission reduction attained under each measure adopted. For estimating the total annual cost the uniform annual cost method is adopted, according to which the fixed cost components are distributed to the useful life years of the measure (Kolb and Scheraga, 1992; Friedrich and Reis, 1999).

$$C_{fixed,\,an} = C_{fixed} \cdot \frac{r}{1 - (1 + r)^{-n}}$$

and, accordingly, added to the variable cost components $C_{total,an} = C_{fixed,an} + C_{variable}$

where:

$C_{fixed,an}$	annual fixed expenditure required by the end of each year of the useful life of the measure [monetary units/year]
r	annual discount rate [-]
n	expected useful life of the measure [years] .

For the built-up of a cost-curve, the measures examined are classified in an increasing order based on the cost required for the unitary reduction of the emissions of each pollutant considered. Thus, the measures that appear first on the cost-curve represent the most “effective” ones in terms of their combined economic and environmental (emission) impacts. A cost-curve may be additionally used either for specifying the measure (or bundle of measures) and the corresponding costs required for achieving a predetermined emission reduction, or for estimating the potential emission reduction achieved through the adoption of specific measures under a given budget.

Impact on air quality

For assessing the impact of each measure on the air pollution levels of the area considered the corresponding emission inventory is constructed, providing temporally and spatially disaggregated information on the emission reduction attained with the adoption of the measure. The starting points for the built-up of the emission inventories are the total emission reductions, depicted in the cost-curves. For measures addressed to the road traffic sector (i.e. introduction of advanced technology vehicles in the car fleet), an emission calculation module is applied. The latter estimates on a road-to-road basis the road traffic emissions based on the COPERT methodology (EMEP/CORINAIR, 1996; Eggleston *et al.*, 1993). Accordingly, simulations of pollutant dispersion and chemical transformation are performed with the EZM system. Core models of the EZM system are the non-hydrostatic mesoscale model MEMO for the calculation of 3-D wind and meteorological fields (Kunz and Moussiopoulos, 1995), the photochemical dispersion models MARS and MUSE which produce 3-D pollutant concentration fields (Moussiopoulos, 1995) and the OFIS model for the long-term simulation of population exposure to high pollution levels (Sahm and Moussiopoulos, 1999).

Economic benefits arising from the adoption of the measure: Externalities

The estimation of the economic benefits (or damages) resulting from the implementation of the measure is based on the results attained with the application of the EZM system (sub-system of OPUS-AIR). The assessment system allows for the monetary evaluation of specific health endpoints and human productivity caused by reductions (or increases) in air pollutant ambient concentrations. Impacts (and therefore benefits/damages) to other than human receptors (e.g. buildings, crops, etc.) are not accounted for. The assessment is based on the concept of the damage function approach enabling the internalisation of the external costs caused by any form of environmental degradation (Cumberland and Kahn, 1982; Dixon *et al.,* 1994; World Bank, 1998). The calculation is conducted with the aid of selected exposure–response functions for specific pollutants and information on the monetary valuation of specific health endpoints. These are summarised by Tourlou (2000). It is pointed out that the exposure–response functions that are currently included in the system’s database correlate ozone, nitrogen dioxide and carbon monoxide impacts with a variety of health endpoints ranging from hospital admissions due to respiratory illness or asthma symptoms to premature mortality. Thus, the total benefit ($C_{total,benefit}$) is expressed as a function of the number of the unfavourable implications over all environmental impacts avoided (or not) after a measure’s adoption ($\Delta_{cases,i}$, i = 1, …, n) and the monetary value contributed to each of these implications ($C_{benefit,i}$).

$\Delta_{\mathrm{cases,i}}$ are calculated through the following expression:

$$\Delta_{cases,i} = R_{i,p} \times \Delta \mathrm{conc}_{\mathrm{p}} \times \mathrm{pop}$$

where:

$R_{i,p}$	correlation coefficient between the pollutant's p concentration variation and the probability of experiencing or avoiding a specific environmental impact *i* (exposure – response function)
$\Delta conc_p$	change in pollutant's p concentration after the adoption of the measure
pop	population units exposed to pollutant p.

Krupnick and Cropper (1992) define $C_{benefit,i}$ as the amount a person is willing to pay in order to avoid experiencing an incidence of a specific health endpoint (WTP value).

As regards human productivity, the suggestion of Crocker and Horst (1981) is adopted, which correlates the daily wage variations of employees working outdoors with changes in daily average ozone concentrations.

Application of the system to the Greater Athens Area

In order to confirm the applicability and reliability of the OPUS-AIR system an exemplary application to the Greater Athens area (GAA) was performed. The topography of the region along with wind statistics for the period of simulation, are shown in Figure 2.

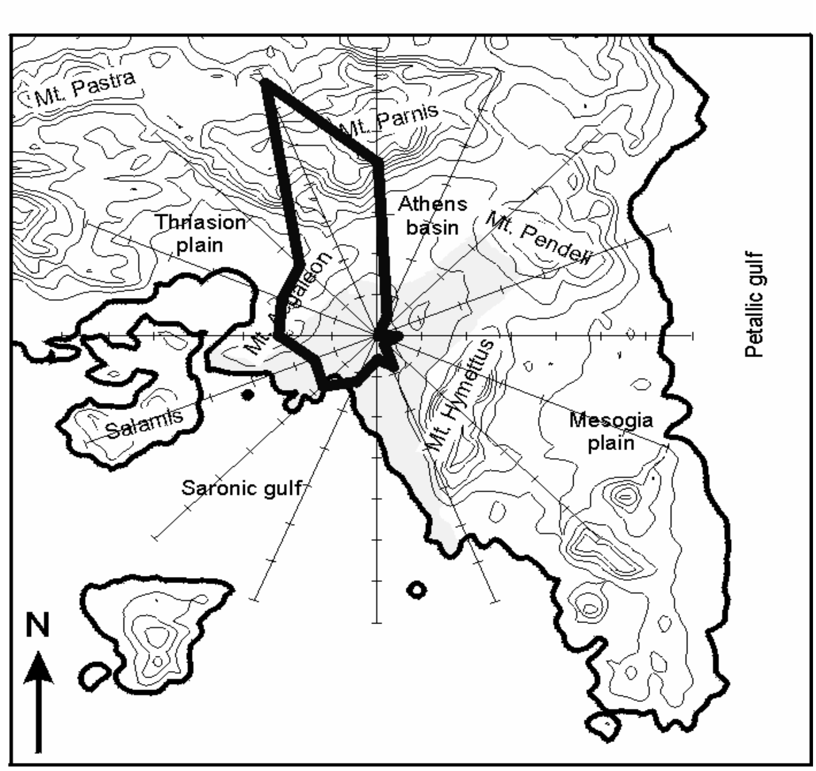


Figure 2. Topography of the Greater Athens area (GAA) and statistical data for the wind direction (the continuous line shows the frequency of the specific wind direction) during the period 1 April - 30 September 1990. Altitude isopleths are contoured at 100 m.

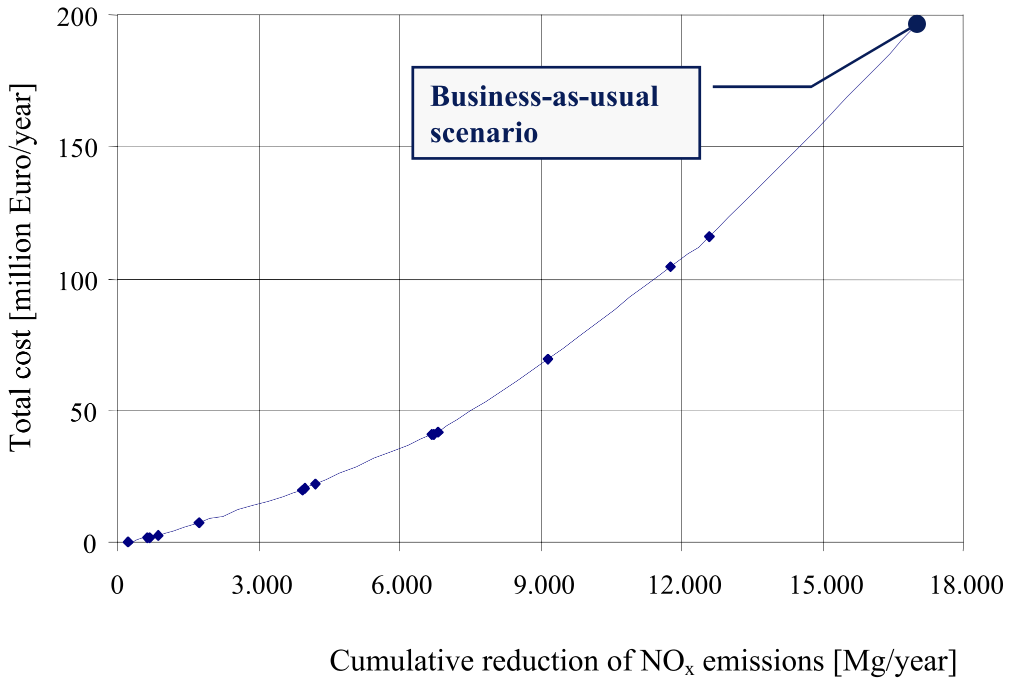
The system was applied for analysing and evaluating the impact of various air quality regulations concerning technical measures for the reduction of NO_x and NMVOC emissions from the most important emission sources of the area (e.g. road traffic, industrial and commercial units and use of solvents). These legislative modulations have already been implemented, or will be implemented in Athens by the year 2010. Apart from the "business as usual" scenario which assumes full compliance with the European legislation until the year

2010, two hypothetical situations involving 50% reductions of the total NO_x and NMVOC emissions on top of the "business as usual" scenario were simulated. The assessment was performed for the period 1990-2010, considering the year 1990 as the "base case" scenario to serve as the reference for the evaluation of the proposed measures.

Implementation costs and expected emission reductions in the period 1990-2010

In order to achieve full compliance with the European legislation, as amended through Directives 99/30, 99/13 and 99/32, various measures have already been adopted or need to be adopted in Athens for the reduction of pollutant emissions from road traffic, energy and solvent-use sectors. In total 50 emission control measures were analysed by estimating their implementation costs and the corresponding emission reductions achieved with their adoption. Accordingly, the total costs for reaching compliance until the year 2010 along with the expected reductions in NO_x and NMVOC emissions in Athens were calculated on an annual basis for the period 1990-2010. It should be noted that the requirements of the "business as usual" scenario (e.g. reaching compliance with the European legislation by the year 2010) claimed for complete implementation of the measures addressed to the transport sector and partial adoption of the measures proposed for the other two sectors. In order to obtain the corresponding values for the additional scenarios for the year 2010, the cost-curves for the period 1990-2010 were constructed and the potential of either imposing full adoption of the measures examined or introducing new measures was investigated (Tourlou, 2000).

The resulting cost-curves for NO_x and NMVOC for the road transport sector are shown in Figure 3. Figure 4 presents the NO_x and NMVOC cost-curves for the energy and the solvent use sectors, respectively. The application point of the EZM system under each scenario examined is marked on each cost-curve.



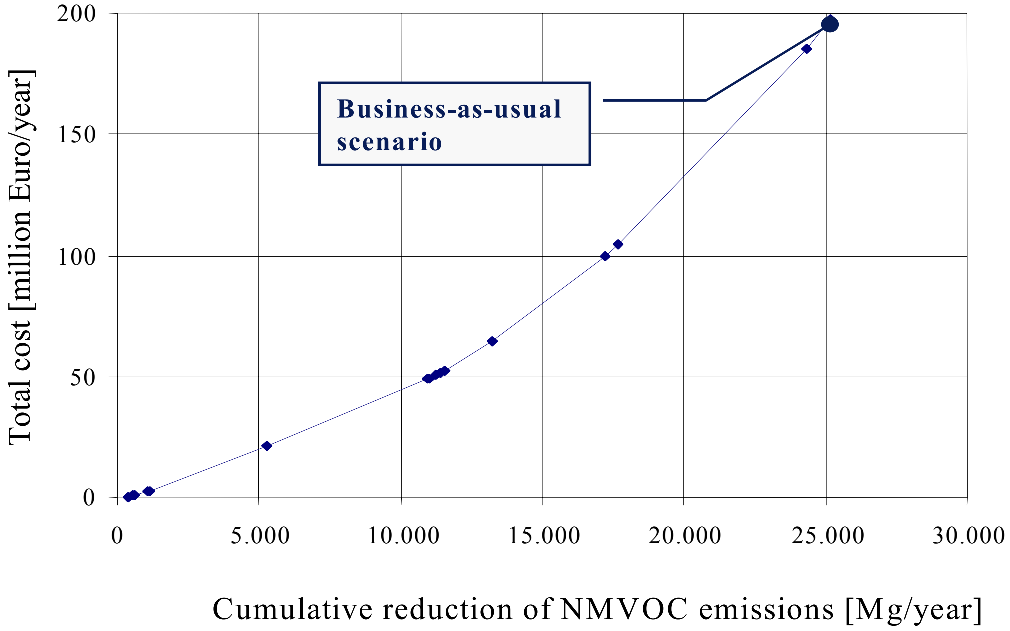


Figure 3. Cost-curves for NO_x (upper part) and NMVOC (lower part) for the road transport sector in the GAA. Each point on the curves indicates an emission reduction measure. The beginning of the axes corresponds to the "base case" scenario (year 1990).

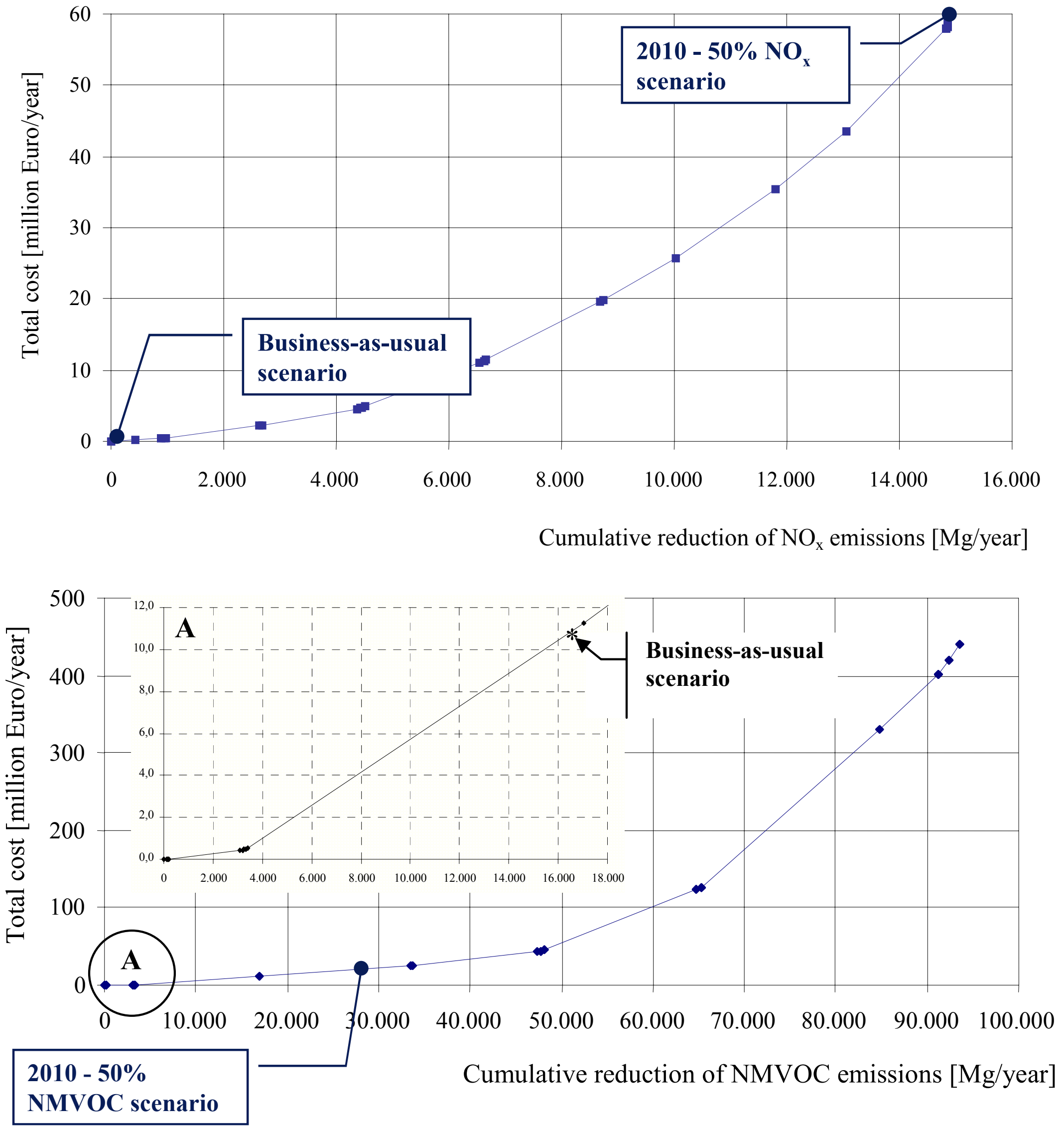


Figure 4. Cost-curves for NO_x (energy sector) and NMVOC (solvent use sectors) in the GAA (upper and lower part, respectively). Each point on the curves corresponds to an emission reduction measure. The beginning of the axes corresponds to the year 1990.

According to Figure 3, the implementation of the “business as usual” scenario imposed the adoption of all the transport-related measures (cf. application point of the EZM system), with a corresponding cost of approx. 200 million Euro. In order to achieve full compliance with the European legislation however, additional measures addressed to the energy and solvent use sectors had to be adopted, thus increasing the cost of the specific scenario by almost 10 million Euro / year (cf. Figure 4).

The simulation of the 50% NO_x reduction on top of the “business as usual” scenario imposed a 19500 Mg/year reduction of the total 2010 NO_x emitted quantities. Since the application of the “business as usual” scenario claimed for full adoption of the road transport measures included in the cost-curves of Figure 3, this additional reduction in NO_x emissions could only be achieved by implementing the measures proposed for the energy sector. However, the measures in the NO_x cost-curve for the energy sector lead to an overall reduction of approximately 15000 Mg/year and therefore, failed to meet the scenario requirements (cf. Figure 4, upper part). This lead to the conclusion that additional measures were required for reaching the emission reduction target of this scenario. On the contrary, the reduction of NMVOC emissions by 50% was accomplished by the adoption of a relatively limited number of the measures introduced for the solvent use sector (cf. Figure 4, lower part). The overall results of the cost-effectiveness analysis are summarised in Figure 5.

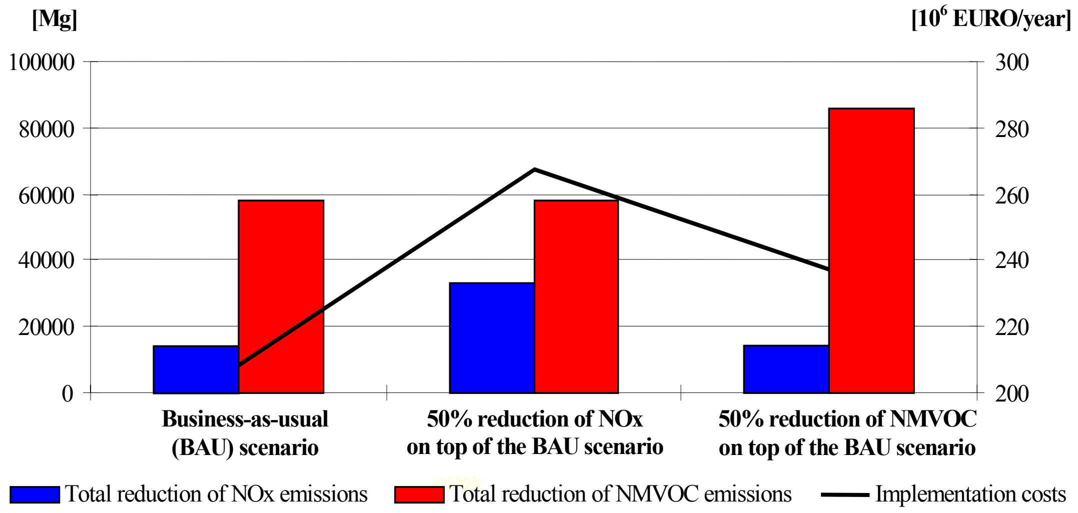


Figure 5. Impact of the emission reduction scenarios on the total NO_x and VOC emissions in the GAA (bars, scale on left axis) and corresponding implementation costs (line, scale on right axis).

As mentioned, the annual implementation costs of the “business as usual” scenario are estimated to almost 210 million Euros. Further reductions of NO_x and NMVOC emissions induce increased costs, which in the case of NO_x are estimated to be at least 270 million Euros per year (cf. previous paragraph).

Impact on air quality

For assessing the impact of the 2010 emission reduction scenarios on the air pollution levels in the GAA the EZM system was applied for a 3-month summer period (between 1 April – 30 September), assuming meteorological conditions as in the year 1990 (cf. Figure 2). In order to form a basis for comparing the evolution of pollutant concentrations in the area of interest, simulations were also performed considering the emission situation during 1990.

Selected model results with regard to the impact of the 2010 scenarios on ozone levels are presented in Figure 6. According to model results, in the time horizon of 2010, considering the “business as usual” scenario the situation is expected to ameliorate. These benefits are not counterbalanced by the rather insignificant ozone increase in the urban area itself. A further reduction of 50% in NO_x emissions has an adverse effect on the ozone threshold exceedances in the urban area, while in the rest of the domain the situation remains more or less unchanged as compared to the “business as usual” scenario. On the contrary, an additional 50% reduction in NMVOC emissions results in reductions of both the frequency and the degree of the exceedances in the urban area compared to the “business as usual” scenario.

As regards the impact of the 2010 scenarios on NO_2 levels, it was concluded that both the maximum hourly and the daily average NO_2 concentrations were significantly reduced. The most significant impact was attained with the 50% reduction in NO_x emissions in the year 2010.

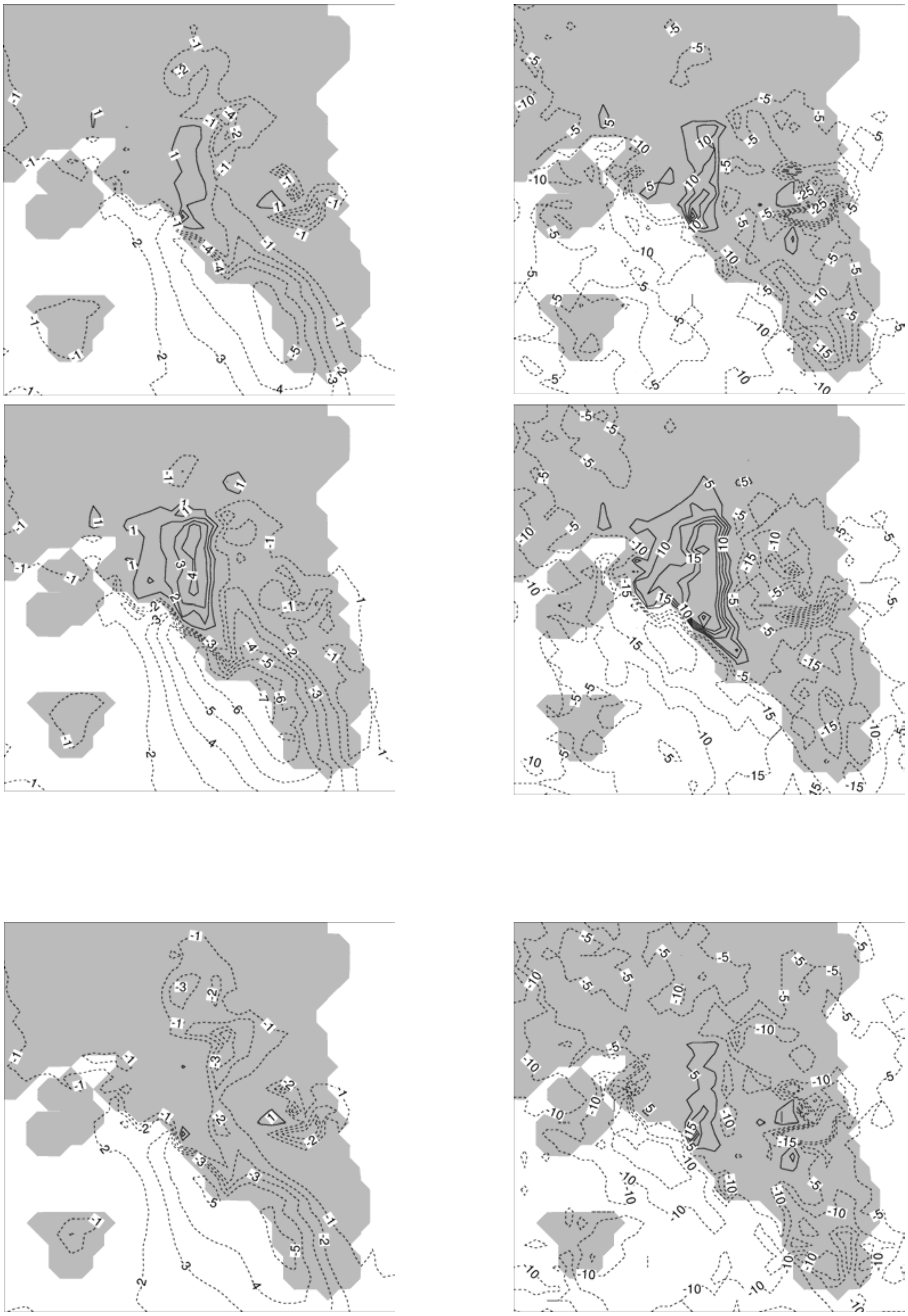


Figure 6. *Upper part:* Calculated differences between the “business as usual” 2010 and the base case scenarios in terms of AOT60 values (left) and number of days of exceedance of the running 8h average of 120 μg/m^3 (right) for the GAA. *Middle part:* Corresponding differences between the 2010 - 50% NO$_x$ and the base case scenarios. *Lower part:* Corresponding differences between the 2010 - 50% NMVOC and the base case scenarios. Dashed curves denote decrease, while continuous curves denote increase of the values.

Cost-benefit analysis

Simulations with the EZM formed the basis for performing a cost-benefit analysis, the latter being oriented towards various effects of ozone, NO_2 and CO to specific health endpoints and workers productivity. The assumptions adopted and the input parameters used for performing this analysis are discussed in detail elsewhere (Tourlou, 2000). As shown in Table 1, this analysis certified that the adoption of all three future scenarios results in quite important economic benefits.

Table 1. Resulting benefits for the three 2010 emission scenarios. Maximum and average annual economic benefits for the inhabitants (including employees working outdoors) of the GAA.

Categories of health endpoints and other implications	**2010 - BAU**		**2010 - 50% NO_x**		**2010 - 50% NMVOC**	
	Max	**Ave**	**Max**	**Ave**	**Max**	**Ave**
Premature mortality	32,970	9,060	47,750	11,780	41,940	9,720
Hospital admissions (all health endpoints included)	210	52	270	65	250	55
Emergency home visits due to asthma crises	7	0.8	5.2	0.6	6.5	0.9
Days of limited productivity due to acute respiratory symptoms	7,165	930	5,480	550	6,950	950
Days of partially limited productivity	244	31	188	18.8	237	32.5
Days with asthma symptoms	5,610	728	4,290	430	4,440	745
Workers productivity	*-5.0*	*-1.5*	*-6.9*	*-3.2*	*-4.7*	*-1.5*
Total annual benefit [thous. Euro]	**46,200**	**10,800**	**57,970**	**12,840**	**53,820**	**11,500**

The most significant impact was attained with the 50% reduction in NO_x emissions on top of the “business as usual” scenario. At the same time, however, the implementation of the specific scenario was found to be relatively expensive as compared to the other scenarios evaluated (cf. section 3.1).

All three scenarios resulted in economic losses with regard to the “workers productivity” category. In contrast to the rest implications examined, the cost-benefit analysis here was based on the daily average ozone concentrations. These, however, were found to slightly increase for most of the days of the simulation period as compared to the base case situation (Friedrich and Reis, 1999; Tourlou, 2000).

Overall assessment of application results

An application of the integrated assessment system was performed for the GAA with the aim to analyse the impact of various ongoing or proposed air quality regulations invoked through the implementation of technical emission reduction measures to the dominant emission sources of the area. The simulation of the air pollution levels in the year 2010 showed that, although the situation is expected to ameliorate with the hypothetical adoption of the measures proposed, air quality exceedances are still predicted in Athens. Among the emission situations examined, the scenario that assumes a 50% reduction of NMVOC emissions on top of the "business as usual" 2010 scenario was found to lead to a substantial air quality improvement. A corresponding reduction in NO_x emissions had, as expected, an adverse effect on ozone levels. At the same time however, the latter scenario resulted into comparatively significant economic benefits, which were primarily caused by the substantially decreased NO_2 concentrations in the area. On the other hand, since the expected reduction of NO_x emissions could not be accomplished with the bundle of measures introduced in the NO_x cost-curves (thus implying that additional measures were required), this scenario was, in parallel, the most expensive among the ones evaluated.

Comparison of the net cash flows (results of the cost-effectiveness and cost-benefit analyses) indicated the "business as usual" scenario as the most profitable solution, without however obtaining a significant eminence against the rest scenarios. The air quality criterion though, was not met (air quality limits were still exceeded in the area).

It should be stressed out that a straightforward comparison of the implementation costs with the corresponding benefits obtained for the scenarios examined shows that the costs far outweigh the economic benefits. The reader should however, bear in mind that the cost-benefit analysis was based on the monetary evaluation of a restricted number of health endpoints, thus focusing on human receptors only. The fact that neither the impacts (and therefore benefits or damages) to other-than-human receptors, nor all pollutants have been taken into account for this analysis, implies that the calculated benefits may be significantly underestimated.

Prior to summarising, there is an additional issue that needs to be briefly addressed: the accuracy of the results obtained through the economic analyses. The determination of all possible errors and the range of uncertainty introduced to the system in every stage of the evaluation procedure are out of the scope of this paper. Having in mind though, that the results produced by the system are subjects to several uncertainties (e.g. inaccurate implementation cost values, empirical exposure-response functions and WTP values, etc.), the costs and benefits calculated for each application must be considered as indicative rather than the actual values.

Conclusions and general remarks

The OPUS-AIR system has been built-up for the evaluation of air pollution abatement strategies taking into account both their impact on air quality and the costs arising from or due to their implementation. The basic innovative elements of the OPUS-AIR may be summarised as follows:

- Quantification of the total cost required for the implementation of a measure.
- Comparative evaluation of alternative abatement solutions on the basis of area– and pollutant– specific cost–curves (e.g. comparison of (mutually divergent or not) investment options on the basis of the cost-effectiveness theory).
- Assessment of measures through the application of a comprehensive air quality model system (e.g. evaluation of the impacts on ambient pollution concentrations).

- Internalisation of the external cost caused by any production procedure or anthropogenic activity and quantification of the economic benefit resulting from the application of any emission or pollution abatement option.

The application of OPUS-AIR to the GAA focuses on the monetary evaluation of specific health endpoints and human productivity caused by reductions (or increases) in air pollutants ambient concentrations. Impacts and (therefore benefits/damages) to other than human receptors (e.g. buildings, crops) are not accounted for. In addition, it is oriented towards the implications of three pollutants to specific health endpoints and workers productivity, whereas side effects are experienced due to the exposure to various air pollutants. The concentration–response functions that are currently included in the system's database correlate ozone, nitrogen dioxide and carbon monoxide impacts with a variety of health endpoints ranging from hospital admissions due to respiratory illness or asthma symptoms to premature mortality. It is of great importance to remark that the estimated benefits are underestimated since the corresponding figures for other than human receptors are not accounted for and that the impact of introducing more pollutants into the analysis remains unknown.

Further development

The quantification (internalisation) of the external costs caused by air pollution and environmental degradation is among the innovative features of OPUS-AIR. As regards the GAA exemplary application presented in this paper, the cost-benefit analysis was conducted without accounting for the consequences of air pollution in other than human receptors. Although the externalities accounted for by the OPUS-AIR system focus on human receptors, the introduction of appropriate exposure-response functions for specific pollutants is currently being elaborated, in order to take additionally into account the impact of air pollution on buildings, materials and other-than-human receptors. The monetary evaluation of impacts on buildings and materials and other than human receptors, as well as the consequences of specific impacts on human receptors, is currently being introduced.

Another line of development refers to the introduction of Multiple Objective Linear Programming (M.O.L.P.) for selecting optimised intervention bundles. Objective functions summarize the total implementation costs of the proposed interventions that are subject to constraints of multi-pollutant emission reductions. Inversely M.O.L.P. is being introduced in order to find the optimum solution of the adoption of specific measures, which maximizes the reduction of multi-pollutant emissions under a given budget. M.O.L.P. supplements the cost-curve approach and contributes to the optimisation of emission control measures.

As a final remark, OPUS-AIR system forms a reliable tool for the objective assessment of the most cost-effective packages of measures, the latter being allocated according to the particular features and needs of the areas examined.

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References

Crocker T.D. and R.L. Horst; Hours of work, labor productivity and environmental conditions: A case study*, The Review of Economics and Statistics* **63** (1981) 361-368.

Cumberland J.H. and J.H. Kahn; The estimation of marginal damage functions: An assessment of the information requirements, *Northeast Regional Science Review* **12** (1982).

Dixon J.A., L.F. Scura, R.A. Carpenter and P.B. Sherman; Economic Analysis of Environmental Impacts, Earthscan Publications, London (1994).

Eggleston S., D. Gaudioso, N. Gorissen, R. Joumard, R.C. Rijkeboer, Z. Samaras and K.-H. Zierock; CORINAIR Working Group on Emission Factors for Calculating 1990 Emissions from Road Traffic, Volume 1: Methodology and Emission Factors, Commission of European Communities Document, ISBN 92-826-5571-X, Luxembourg (1993) 116 pp.

EMEP/CORINAIR: Atmospheric Emission Inventory Guidebook (ed. G. McInnes) First Edition, European Environmental Agency, Copenhagen (1996).

Friedrich R and S. Reis; Tropospheric Ozone Abatement - Developing efficient strategies for the reduction of ozone precursor emissions in Europe, (R. Friedrich and S. Reis, eds.), Springer Publications (1999).

Kolb J.A. and J.D. Scheraga; Discounting the benefits and costs of environmental regulations, *J. of Policy Analysis and Management* **9** (1992) 381-390.

Krupnick A.J. and M. Cropper; The effect of information on health risk valuation*, J. of Risk and Uncertainty* **5** (1992) 29-48.

Kunz R. and N. Moussiopoulos; Simulation of the wind field in Athens using refined boundary conditions, *Atmos. Environ*. **29** (1995) 3575-3591.

Moussiopoulos N; The EUMAC Zooming Model, a tool for local-to-regional air quality studies, *Meteor. Atmos. Phys.* **57** (1995) 115-133.

Sahm P. and N. Moussiopoulos; The OFIS model: A new approach in urban scale photochemical modelling, EUROTRAC Newsletter 21/99, EUROTRAC-ISS, Garmisch-Partenkirchen (1999) 22-28.

Tourlou P.M.; Integrated Assessment of Photochemical Pollution Abatement Strategies in Urban Areas, PhD Thesis, Department of Mechanical Engineering, Polytechnic School, Aristotle University Thessaloniki (2000) 149 pp.

World Bank; Pollution Prevention and Abatement Handbook, Washington, D.C (1998).

Yu Po, L; Forming Winning Strategies - An integrated theory of habitual domains. Springer-Verlag, Berlin, Heilderberg (1990).